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K M 125 The information collected directly was supplemented by the replies to two questionnaires issued by the Medical Department to district medical officers, medical missionaries, chiefs of tribes and others interested in the investigation. One questionnaire dealt with the dietary customs of natives and the other with the incidence and etiology of ulcers.

II.—FIELD WORK.

(a) Dietary Customs and Incidence of Disease in the Kikuyu and Masai Reserves.

K M 114 Dr. J. W. Foster was sent out from the Rowett Research Institute to carry out this part of the investigation, and Dr. J. C. J. Callanan, of the Medical Service in Kenya, was specially detailed to work with him for the first five months.

K M 121 262 The two reserves chosen for the investigation were the Kikuyu and Masai, the choice being made on account of the fact that the reserves adjoin while the dietary customs of the tribes are very different, the Akikuyu * being almost exclusively vegetarian and the Masai chiefly carnivorous.

K M 126 [114] The two Reserve areas were visited alternately during a period of over a year and a half, each trip occupying two or three months. Samples of all foodstuffs in common use were collected and despatched to the Rowett Institute for analysis. The samples consisted of articles of diet in the raw state, cooked foods, edible earths, salt substitutes, and natural mineral waters used in cooking.

K M 125 A physical examination was made of 6,349 Kikuyu and 1,546 Masai † adult natives of both sexes and all ages. The examination was made under eighteen heads, including stature, weight, chest, abdomen and calf measurements; presence of anæmia; condition of teeth and gums; general physical and muscular development; strength as indicated by the dynamometer; presence of hernia, splenomegaly; ulcers.

A similar examination was made of 2,500 Kikuyu and 254 Masai children. The special object of this examination was to compare the tribal incidence, during the growth period, of osseous deformities, dental caries, periodontitis, anæmia, and general signs of malnutrition.

The subjects examined for physical condition were taken at random from the healthy section of the community in all parts of the Reserves. Great care was taken to exclude any sick native who presented himself. Apart from this, no selection was made, and the records may be taken as representatives of the average native of the Reserves.

An estimation was made of the diseases prevailing in the two tribes. Hospital returns were analysed, but, as it became apparent that, for

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* The prefix "A" in Akikuyu has a collective sense, the term "Akikuyu" referring to the tribe as a whole, while the term "Kikuyu" has only an adjectival significance.

K M [161]

† It should be noted that the estimated populations of the Kikuyu and Masai Reserves at the end of 1929 were respectively 795,934 and 48,547.

many reasons, this did not give a complete picture of tribal morbidity, the plan was also adopted of travelling with a medical outfit and offering free treatment to sick natives. By this means, many thousands of natives were seen who, on account of such considerations as the distance involved, or inherent shyness, would never have appeared at a hospital.

(i) *The Akikuyu.*

The Akikuyu are a Bantu tribe, numbering about ¾ of a million, who occupy part of the highlands of Kenya between the equator and 1 deg. south. They are agriculturists and live on a diet which is chiefly vegetarian. Beef may be almost entirely discounted from the diet ; game, fish, birds and eggs are ignored, and the eating of goats and sheep is almost confined to the old men. A goat or ram is slaughtered only at a marriage or other feast, or to remove "thahu" (ceremonial uncleanness). On such an occasion, the old men eat the entire animal with the exception of one leg and the viscera, which are divided among the women and children. Meat cannot therefore be regarded as forming a regular part of the dietary. The amount eaten by the women and children must be insignificant. It should be noted, however, that although so little meat is eaten the natives possess large herds of goats. These are used mainly as currency, instead of as a source of supply of milk and meat.

There are very few cattle in this Reserve and those are in the hands of a wealthy minority. The milk yield of native cows, under native management, is very low. In most cases it probably does not exceed 100 gallons per annum. Hence, very little cow's milk is available.

The great bulk of the Kikuyu diet consists of cereals, tubers, plantains, legumes and green leaves. The males show a preference for cereals and tubers, 60 per cent. of their diet consisting of maize or millet, and sweet potatoes accounting for a further 25 per cent. The women also subsist chiefly on these articles, but add more liberal quantities of legumes and plantains and have a virtual monopoly of the green leaves.

In addition to natural foodstuffs, a common article of diet, especially among the women, is the earth from salt licks. In all the native markets these edible earths are displayed for sale. Another common practice throughout the Kikuyu Reserve is the preparation of a salt substitute by the burning of swamp plants. During recent times Magadi soda has largely replaced these salt substitutes. Evidence was obtained that the consumption of edible earths and plant ashes is more common amongst the women than the men. It appears that the practice is for young children of both sexes to be given food containing these salt substitutes up to about the age of 5 years. Afterwards the custom appears to be confined to the females, and the young boys and men get little, if any. In addition to these salt substitutes, water from special springs is highly esteemed for human consumption and is used in cooking.

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no marked tribal immunity to pulmonary conditions, and that any superior resistance they may show under natural conditions is probably correlated with either superior diet or environment.

It was the general impression of the field worker that disease was less common amongst the women in the Kikuyu reserve than amongst the men. This impression is supported, as far as helminthic infection is concerned, by observations by Vint (1929). In a series of post mortem examinations of 104 cases of men and women, only 19, or 18 per cent., were found free from helminthic infection. Of the 104 cases, 11 were women and 4 of them, or 36 per cent., were free from helminths. Similar evidence is found in clinical records of examinations of fæces at Nairobi Medical Laboratory in which 74 per cent. of men were found to be infected and only 49 per cent. of the women.

Tuberculosis also, as judged by hospital statistics, appears to be less common in women than in men. Wilson (1928) says " There is one noteworthy feature of all our tuberculosis statistics, and that is the overwhelming proportion of male patients," and he also states that pulmonary tuberculosis is rare in native children.

There is, of course, always the difficulty about hospital data that it may be argued that women do not go to hospital as much as the men, but even if this is true, since pulmonary conditions constitute a large proportion of all hospital cases, it seems unlikely that the proportion of women with tuberculosis going to hospital would be lower than that of men.

These indications, taken along with the marked superiority of girls over boys as described from the clinical examination of children, and the admittedly superior general condition of women as compared with men, point to an effect on general condition and health of the difference in diet of the sexes. There can be little doubt that the dietary of the young children, the girls and the women, is better balanced than that of the older boys and men, and this appears to be clearly reflected in differences in physique and health.

III.—LABORATORY AND HOSPITAL WORK.

The laboratory work was carried out by the late Dr. J. M. Henderson in conjunction with Dr. Kelly, Dr. Harvey and other members of the staff of the Medical Research Laboratory in Nairobi, which is under the direction of Dr. W. H. Kauntze. It included analyses of hospital and prison diets and metabolism experiments on native prisoners to determine the effect on weight, composition of the blood, and retention of calcium and phosphorus, of certain additions to these diets.

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It is obvious that the subjects were roughly in calcium equilibrium, some showing small negative and others small positive balances. The fact that cod liver oil alone had no effect in promoting an increased calcium retention is probably due to the low calcium intake, 0·3 gm. Ca per day as compared with a probable maintenance requirement of 0·45 gm. per day. This finding is in agreement with those of Schabad and Sorochowitsch (1911) and Schloss (1914), who found that the use of cod liver oil was not always followed by an increased retention of calcium. It is also in agreement with the work of Sherman and Macleod (1925) on rats, in which they found that the addition of cod liver oil to a diet low in calcium had no effect on calcification of the bones.

In the groups receiving the mineral mixture, the balances were usually definitely positive, and the retention was obviously highest in the mineral group receiving cod liver oil. This is in agreement with all recent knowledge of the effect of vitamin D on calcification.

Experiment 2.—*Growing Boys.*

The results of the first experiment with full grown men had shown that the addition to the calcium-poor prison diet of either calcium or cod liver oil was followed by a rise in the level of calcium in the blood, and that the addition of calcium or calcium and cod liver oil caused an increased retention of calcium. Since the calcium requirements of adolescents are higher than those of full-grown men, it was decided to carry out balance experiments with youths on this diet to determine (1) whether the calcium intake was sufficient to maintain equilibrium, and (2) the effect on the calcium balance of additions to the diet of (*a*) mineral salts, (*b*) cod liver oil, and (*c*) milk. It was thought that such experiments might give some indication of the calcium requirements of adolescents, a subject on which there is little information in the literature.

For this experiment, five subjects were chosen as being reasonably comparable in age, physical development, general condition and type of prison employment. The average age of the five was 16 years. One of them was a Masai and the other four were Nandi, whose customary diet is approximately the same as that of the Masai. All were employed on gardening work in Nairobi prison where they were serving long term sentences.

As a preliminary, the Wassermann test was made on the five boys : all were negative. Stools were examined for parasites and blood for evidence of malaria. Similar examinations were made periodically throughout the experiment. Treatment was carried out as required and did not interfere with the experimental work.

The experiment was divided into three periods as follows :—

(1) A preliminary period of three weeks during which the subjects were on the usual long term prison diet.

(2) A period of five weeks during which the prison hospital diet replaced the prison diet.

(3) A supplement period of nine weeks in which the additions as specified below were made.

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The basal diets were as already described (p. 20). The additions were as follows :—

Prisoner's No.	*Supplement fed.*
2640	None.
2413	15 c.c. cod liver oil.
1217	Mineral mixture.
2415	Mineral mixture+15 c.c. cod liver oil.
2534	1 pint cow's milk.

The mineral mixture was identical with that used in the experiment just described. The calcium added to the ration daily in the mineral mixture was 0·68 gm. Ca. From analysis, the calcium content of the milk fed to subject 2534 averaged 0·77 gm. Ca per day. The milk was boiled, as is customary in the Colony.

Results.—(1) *Weight.*

Increases in weight occurred in each case. The largest gains were made by the boys receiving milk and minerals with cod liver oil.

(2) *Blood Calcium.*

The serum calcium was estimated in each of the boys at the beginning of the experiment. The values varied from 10 mg. to 10·6 mg. per 100 c.c. At the end of the supplement period they were practically the same. The average of all the determinations was 10·3 mg., which is within the limits of the normal European range. It is interesting to compare these figures with the previous results on adult prisoners. The latter were all Kikuyu or from tribes with a diet similar to that of the Kikuyu. The average for the 42 cases was 9·2 mg. On the other hand, the boys whose average was 10·3 mg. included one Masai and four Nandi, all with a similar dietary including large quantities of milk. Before admission therefore they would all have had a very high intake of calcium.

(3) *Calcium Balances.*

The calcium balances of each of the five subjects were determined on nine occasions, twice on the prison diet, three times on the prison hospital diet, and four times during the supplement period. The collection period in each case was 96 hours. The following table shows the balances calculated to 24 hour periods.

Average 24 Hour Balances.

Period.	2640 B.	1217 M.M.	2415 M.+C.L.O.	2534 Milk.	2413 C.L.O.
Prison diet .. .. (Ca intake, 0·3 gm.)	+0·0385	−0·0354	−0·2969	−0·1506	+0·0051
Prison hospital diet .. (Ca intake, 0·346 gm.)	−0·0067	−0·1646	−0·2459	−0·0988	−0·2001
Supplement	+0·0434	+0·2509	+0·0962	+0·5058	−0·1364
Ca intake in each case in supplement period.	0·346	1·03	1·03	1·116	0·346

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It will be seen from the table in which the calcium balances are calculated on the analyses already quoted (p. 20), namely, 0·3 gm. for the prison diet and 0·346 for the prison hospital diet, that three of the subjects were on a negative balance on both diets, and two on a positive balance on the former, and a negative balance on the latter diet. We have seen that the calcium in these diets might vary slightly owing to variations in the composition of the beans and potatoes used, but even allowing for the highest figure obtained by analysis, 0·38 gm., the subjects could not have been more than in equilibrium. In growing boys, retention of calcium would have been expected, and indeed, in a later experiment with boys, a small positive balance was found. It is possible that in this experiment, the balance may have been affected by the high calcium intake of the boys on their customary diet before admission to the prison.

Since all the subjects were on the same basal diet, the figures showing the effect of supplement feeding on the calcium balances are comparable. No. 2640 on the basal ration was practically in equilibrium throughout the three periods. The addition of the mineral mixture (No. 1217) changed an apparently negative balance of about 0·1 gm. on an average, to a positive one of 0·25 gm. In No. 2415, the addition of the mineral mixture and cod liver oil changed a negative balance of about 0·27 gm. to a positive one of about 0·1 gm. In No. 2413, the feeding of cod liver oil alone reduced the negative balance of the immediately preceding period, but as compared with the average of the two unsupplemented periods, had no beneficial effect. The greatest difference was seen in the case of No. 2534, the addition of milk changing a negative balance of 0·125 to a positive one of 0·51.

The difference in the calcium balance made by the addition of milk to the diet was therefore 0·63 gm. per day, and the amount of calcium supplied in the milk was 0·77 gm. In the case of the mineral mixture, the amount added was 0·68 gm. and the difference made in the balance was 0·35 gm. This indication of a higher availability of the calcium in milk as compared with that of calcium supplied in other forms is in accordance with the observations of Sherman and Hawley (1922), who found that in children the assimilation of calcium from milk was much higher than from vegetables. The fact that cod liver oil did not materially affect the calcium balances in this experiment would appear to indicate that, in these prison diets, the lack of calcium was of more importance than lack of the factors which affect calcium assimilation. We have already referred to similar findings by other workers.

It is of interest to consider the maintenance requirement in the light of the figures given in the table of calcium balances. The average negative balance of the five subjects throughout the two periods of unsupplemented diet was 0·116 gm. with an average intake of about 0·323 gm. If these figures be accepted as correct, the minimum requirement for equilibrium would appear to be

0·44 gm. per day, which is in close agreement with Sherman's estimate of 0·45 gm.

Assuming that the maintenance requirement is 0·44 gm. per day, the addition of 0·68 gm. in the mineral mixture would leave a surplus of roughly 0·59 gm. for storage. Of that amount, 0·25 gm. was actually retained, i.e., about 40 per cent. In the case of the supplement of milk, there was a surplus of 0·68 gm., and an actual storage of 0·51 gm. or 75 per cent.

Balance Experiment 3.

The results of the second balance experiment showed that the addition to the calcium-poor basal diet of either milk or a mineral mixture resembling in composition the ash of milk was followed by increased retention of calcium. As cod liver oil without calcium had little effect on the retention, it was assumed that the chief deficiency in the diet was that of calcium itself. To verify this assumption, another experiment was made in which calcium was added to the diet in the form of calcium carbonate and bone flour, the latter supplying inorganic phosphorus as well as calcium. Both are cheap sources of calcium. Milk and green vegetables are expensive, and at certain seasons difficult to obtain, while the elaborate mineral mixture used entailed considerable work in preparation and was also expensive.

For this experiment five Nandi boys, of an average age of 18 years, were chosen as being comparable in physique and general condition. The preliminary treatment of the subjects and the experimental methods were as in the previous experiment.

The basal diet was the prison hospital diet. Analyses showed the calcium in a day's ration to be 0·38 gm. and the phosphorus 2·89 gm. Both were slightly higher than in the last experiment. The calcium carbonate used was a pure sample; the bone flour was a finely ground local product. The supplement feeding was arranged as follows :—

Period.	No.	Diet.
Pre-period—		
Four 2-day collections ..	—	All on prison hospital diet.
First supplement period—		
Eight 2-day collections ..	1901	$CaCO_3$.
	2251	Control.
	2413	Bone flour.
	2428	Bone flour.
	3341	$CaCO_3$.
Post Period—		
Six 2-day collections.. ..	—	All on prison hospital diet.
Graded supplement period—		
Five 2-day collections ..	1901	Bone flour.
	2251	$CaCO_3$.
	2428	$CaCO_3$.
	3341	Bone flour.

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calcium deficient diet, the first effects of increasing the intake of calcium would be in the consolidation of the existing bone rather than in increased rate of growth in length. The suggestion of a favourable effect on the younger boys, however, points to the desirability of further tests. It would also be of interest to determine in tests carried over much longer periods whether increases such as those procured in this experiment represent merely temporary stimulation of growth, or whether they would be maintained and represent true increases in height.

After supplement feeding was stopped, the measurements of height and weight were continued from March to September. The results are tabulated below.

Diet.	Average heights—inches.			Average weights—lb.		
	March.	September.	Increase.	March.	September.	Increase.
Basal	62·533	63·192	0·659	107·067	108·442	1·375
Maize	62·955	63·741	0·786	107·366	108·071	0·705
Maize and bone flour ..	62·863	63·540	0·677	107·669	109·065	1·396
Milk	62·986	63·743	0·757	112·871	111·643	−1·228

It will be seen that the rates of increase in both height and weight are less in all groups than in the period August to March. As regards height, the beneficial effects of the supplements appear to be carried over into the post period, but only the maize and bone flour group continued to put on weight at a greater rate than the controls.

The superiority of the results with milk during the feeding tests is in agreement with the results of milk feeding experiments on school children in Scotland (Orr, 1928, Leighton and Clark, 1929). In these tests, made on 1,157 children, quantities of milk varying from ¼ of a pint to 1 pint of milk, according to age, were fed from November, 1927, to June, 1928. Half of the children received milk and the other half a supplement of biscuits equal in caloric value to the milk. The average increases in height in the milk group were 23·5 per cent. greater than in the controls, and the average increases in weight 45·37 per cent. greater.

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(c) The Etiology of the Tropical Ulcer.

Since tropical ulcer is so common amongst the Kikuyu and comparatively rare amongst the Masai, and since the dietary habits of these two tribes are very different, it was thought that some deficiency in the diet might be a predisposing cause. A study of the etiology, with special reference to the nutritional state of the patients, was therefore made. Clinical data, with notes on the effect of different forms of dietary treatment, were collected in 140 cases, and blood

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examinations were made to ascertain whether any differences could be detected between ulcer and non-ulcer cases.

(i) *Description of Ulcers.*

The ulcers occur chiefly on the lower outer part of the legs, most commonly of all on the lower outer aspect of the left leg. On admission to hospital they vary in diameter from about 1 to 6 ins., the edges being raised and of low vitality, and the floor covered with blood-stained exudate and foul-smelling debris. In many cases tendons protrude and are necrosed, and in some the bone is exposed and possibly dead or dying. Bacteriological examination showed a characteristic combination of Vincent's fusiform bacillus and a spirochæte. It should, however, be noted that each of these organisms has been regarded as accidental contamination, *e.g.*, by Mendelson (1918) in the case of the spirochætal infection, and Mei (1920) in the case of Vincent's bacillus.

(ii) *Associated Conditions.*

(*a*) *Trauma.*—In 125 cases, for which histories were obtained, trauma was said to have occurred in 92. Among farm labourers a prick by hard sisal leaves was the commonest injury. Such slight injuries must, however, be of almost daily occurrence in natives with bare feet and legs, either in the bush in the case of those in the reserves or in labour gangs, more especially on sisal plantations. There appears from the replies to the questionnaire on this subject to be a concensus of opinion amongst medical officers that immediate treatment of injuries, however slight, leads to a decrease in the occurrence of ulcers, and protection of the feet and legs greatly reduces the number of cases. While, therefore, it must be admitted that slight injuries do doubtless precipitate the development of ulcers and determine their location, it is difficult to believe that they are the sole cause. Indeed, there appears to be a general impression that, although trauma may be the immediate exciting cause, there is an underlying condition which predisposes to the development of ulcer, and retards its healing. Malaria, syphilis and intestinal parasites have been suggested as predisposing causes.

(*b*) *Malaria.*—It has frequently been stated that the incidence of tropical ulcer shows a close parallelism with that of malaria. In the present investigation, 123 ulcer cases were examined for malaria, and 28, i.e., 22·8 per cent., were positive. According to observations by Colonel James (1929), the proportion of native children whose blood contains malaria parasites may vary from 33 to 80 per cent., and Brennan (1926) found in Kisumu that of 1,000 slides examined for malaria parasites, 507 were positive. Anderson, T. F. (1929) in Teita found the incidence of malaria in adults to be 30 per cent., and Ross (1929) in the Kavirondo Reserve, found an incidence of 35 to 50 per cent. in the general population. It is obvious that, in the cases studied, the incidence of malaria was not higher than that in the general population.

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From the replies to the questionnaire issued by the Medical Department, it is difficult to establish any correlation between malaria and ulcers, the incidence of malaria in ulcer cases, as stated by different correspondents, varying from 0 to 100 per cent. As far as this brief study goes, there is, therefore, no evidence that malaria is an important predisposing cause of ulcer.

(*c*) *Syphilis.*—It has been suggested by some writers, *e.g.*, Stitt, that most cases of tropical ulcer are syphilitic in origin. In the present study of 123 cases, 15 per cent. showed a positive Wassermann. The following table shows how this compares with the percentage of positive reactions in sections of the general native community examined :—

Subjects.	*No. examined.*	*Percentage with definitely positive Wassermann.*
Kenya police	55 ..	29
Prisoners in Nairobi Gaol ..	100 ..	43
Ulcer cases from Kisumu ..	165 ..	55
Ulcer cases at native hospital ..	123 ..	15·4

It has to be remembered that a positive Wassermann is found in cases of active yaws. As far as these figures go, therefore, there does not appear to be any correlation between incidence of syphilis and that of ulcers. This is in accordance with results obtained by Halpin (1918), who found only one positive Wassermann in a total of 35 cases examined, and with the observations in Cocos and Perim of Edge (1921), who found no correlation between syphilis and ulcers.

(*d*) *Intestinal parasites.*—In 122 cases examined, 78·7 per cent. were found to be infected with intestinal parasites. Helminthic infection was found in 73·8 per cent. of the cases. These figures are compared in the following table with the incidence as determined by Callanan (1927) in 1,000 cases in the native hospital, including ulcer cases :—

	General hospital cases (including ulcers).	*Ulcer cases.*
Intestinal parasites ..	75 per cent.	78·7 per cent.
Helminths	65·8 „	73·8 „

There is a higher incidence of intestinal parasites, especially helminths, in ulcer cases, but it is doubtful whether the difference is significant. The incidence of intestinal parasites in the general native population varies rather widely. Ross (1929) in the Kavirondo Reserve found the incidence varying from 27·5 to 70·6 per cent. Philip (1927, 1, 2) in the Wateita found an incidence of 61 per cent. in the general population and 97 per cent. in 34 coast prisoners. Briscoe (1929) found 57 to 82 per cent. infected amongst the Wakamba.

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Hence the incidence of parasites in ulcer cases is not conspicuously higher than in the general population, and since in 22 per cent. of the ulcer cases the presence of intestinal parasites could not be demonstrated they cannot be regarded as an important etiological factor.

(*e*) *Tribal, sex, and seasonal incidence.*—The most outstanding feature with regard to the tribal incidence of ulcer is that brought out by the survey (p. 34), namely, the high incidence amongst the Kikuyu, and the relatively low incidence amongst the Masai. This is confirmed by the replies to the questionnaire which state that true indolent ulcer is rare amongst the Masai but common amongst the Wakamba, Kavirondo, Kikuyu, Luo and Lumbwa tribes. Ulcer is relatively uncommon also in the Swahilis. We have not sufficient evidence to enable us to say whether racial differences can be correlated with ulcer, but the prevalence of the condition throughout the tropics makes this appear unlikely. With regard to diet, the difference between the Masai and Akikuyu has already been discussed in the first section of this report, and it is known that the Swahili have a mixed dietary. The diets of the other tribes mentioned above, in which ulcer is common, are somewhat similar to that of the Akikuyu.

As regards sex incidence, of the 140 cases studied in this investigation only 3 were women. This however cannot be taken as any indication of the relative incidence in the two sexes, since a high proportion of the cases in Nairobi Hospital are derived from labour gangs. Of the replies to the questionnaire which dealt with the question of sex incidence, 5 stated that ulcer is more common among men, 2 among women, and 4 that there is no sex difference. Among the subjects weighed and measured by the field worker, there were more ulcers in adult females than in adult males, but among the children examined, ulcers were more common in the boys. In the Kikuyu Reserve at least, the women do most of the hard work and are consequently likely to be more exposed to injury than the men. On the whole, the balance of evidence seems to point to a somewhat higher incidence amongst men than amongst women.

It is interesting to note that the admissions of ulcer cases to hospital commonly increase just as the long rains break. This is a season when disease amongst cattle is said to be more frequent. Since the growth of vegetation, and consequently the diet of both cattle and natives is affected by the rainfall, the high incidence of ulcer at the end of the dry season suggests the implication of a dietary factor.

Indirect evidence in the same direction is afforded by Breinl's (1915) survey of disease in British New Guinea. He found that there was a marked regional difference in the incidence of ulcer depending on the use of sago as the staple article of diet, and the consequent frequent slight injuries from the spines on the leaves and

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trunk of the sago palm. Although Breinl gives no details regarding the dietary, we know from the work of Cilento (1926) and Strong (1927) that the food of the natives of New Guinea is chiefly carbohydrate, and that the general condition and health is poor. Edge also considers that dietary deficiencies play an important part in the etiology of ulcer.

Such information as could be collected in the present study of the etiology of ulcer seems to warrant the tentative conclusion that neither malaria nor syphilis can be regarded as causative agents. The influence of intestinal parasitic infestation, if any, is not prominent. Trauma is probably an important exciting cause, superimposed upon a condition of low resistance, which is probably the most important factor, in as far as it decreases the natural healing powers and increases susceptibility to invasion by the characteristic micro-organisms. This condition of low resistance may possibly be correlated with dietary deficiencies.

(iii) *Effect of Dietary Treatment on Rate of Healing.*

The effect of various additions to the diet on the rate of healing was studied in 140 cases. These were divided between two wards to facilitate the treatment. The ordinary hospital diet (p. 20) was used as the basal diet. The additions consisted of tomatoes, lemons, cod liver oil, a mineral mixture similar to that used in the prison metabolism experiments, and milk. These additions were, at one time, given all together, later the tomatoes, lemons, cod liver oil and mineral mixture were given in one ward, and milk in the other.

In addition to the dietetic treatment, the routine hospital treatment, consisting of saline baths, eusol dressings and fomentations, and, where indicated, scrapings, was continued.

The patients were weighed regularly, and daily clinical notes were taken of the general condition of the patients and the rate of healing of the ulcers. This material does not lend itself to statistical treatment. All that can be given is a descriptive account, with the conclusions reached by the observer from the mass of detailed data recorded in the course of the investigation.

In the first period, all the supplements referred to above were added to the hospital diet for one ward. This was followed by an improvement in general condition of the patients, increase in weight, and " according to the general impression " of the observer, more rapid healing of the ulcers. Later, the milk ration was withdrawn from this ward and given to the control ward, after which no detectable difference was noted in the rates of healing in the two wards. The milk appears, therefore, to have been of as much value as all the other supplements together.

The observer emphasises the fact that in no case, either with the supplements all together, or separately, was there any dramatic improvement in the rate of healing. The only conclusion possible

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was that the supplements improved the condition of the patients, and pari passu with this improvement there appeared to be a more rapid healing of the ulcers.

This conclusion is supported by a consideration of the gains in weight of the patients and the number of weeks required for recovery, a comparison of which affords the only quantitative measure of the effect of supplement feeding. The data are shown in the following table :—

Age.	20–22.	Over 25.	Under 16.	23–25.	17–19.
Number in group	6	23	32	11	19
Gain per man per week in oz.	13·3	12·8	10·6	8·8	8·4
Weeks to recover	8·3	10·2	10·5	11·7	12·9

It will be seen that the rate of increase in weight is not correlated with the age of the subjects.

The conclusion cannot, however, be taken as more than an indication, since it cannot be assumed that all cases were at the same stage and of the same degree of severity, and since some were discharged before healing was complete.

The dietary tests, therefore, showed that none of the substances tried had any marked effect on the rate of healing, but that the rate of healing appeared to be correlated with the general condition of the patients.

(iv) *Blood Examinations in Ulcer and Non-ulcer Cases.*

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In order to ascertain whether ulcers could be associated with any constant deviation from the normal in the composition of the blood or in physiological adjustments, the calcium and inorganic phosphorus content of the blood were estimated, the sugar tolerance and blood pressure determined, and blood counts made in a number of ulcer and non-ulcer subjects.

(a) *Calcium content.*—Estimations of serum calcium were made on 90 prisoners and farm labourers not suffering from ulcers, and on 57 ulcer cases, with 13 Europeans as controls. The following figures show the ranges and averages :—

Serum Calcium—mg. per 100 c.c.

Class of case.	No.	Range.	Average.
Prisoners and farm labourers ..	90	7·3 to 11·0	9·4
Ulcer cases	57	7·0 to 11·2	9·7
Ulcer cases on admission	46	7·0 to 11·2	9·6
Ulcer cases on discharge	11	9·7 to 11·2	10·3
Europeans	13	10·7 to 12·5	11·2

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of blood for phosphorus determinations, 15 gm. urea being given in each case :—

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Urea Concentration Tests.

Inorganic P.		Hours after administration of urea.			
		1.		2.	
Ulcer case.	Mg. per 100 c.c.	Urine vol.	Urea.	Urine vol.	Urea.
		c.c.	%	c.c.	%
1	4·17	310	0·85	130	2·34
2	4·72	200	1·16	80	3·00
3	4·68	162	1·66	72	4·06
4	5·38	115	2·00	70	4·37
5	6·02	610	0·78	80	3·90

It will be observed that the concentration of urea is within normal limits, being in all cases over 2·0 per cent. in the second hour (the accepted standard, Maclean, 1924). Hence the very high blood inorganic phosphorus in ulcer cases cannot be attributed to renal insufficiency. The general fact of an increase in, however, in agreement with what we have seen to occur with diets ill balanced in having an excess of phosphorus and deficiency of calcium.

(c) *Sugar tolerance.*—In 34 subjects, of whom 16 were ulcer cases, the sugar tolerance was investigated. Tests were also made on three Europeans as a control against the possible effect of climatic conditions.

The detailed results are given in Appendix 3. Graph 11 shows the nature of the results obtained. It will be seen that the Europeans conform fairly closely to the standard curve. The natives, on the other hand, show a distinct lag. This is in agreement with tests on Indians by Bhatia and Coelho (1925), who found that those accustomed to a vegetarian diet, chiefly carbohydrate, showed a lag in the rate of return to normal after ingestion of glucose. There is little difference between the curves for ulcer and non-ulcer cases.

(d) *Blood pH and alkali reserve.*—It was intended to investigate the pH and alkali reserve of the blood but, owing to delay in the transit of apparatus, the work had just begun when Dr. Henderson became ill. The only available data are a few preliminary observations on the pH, which showed no marked deviation from the normal.

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(e) *Blood-pressure.*—Blood-pressure estimations were made on a number of Kikuyu, both on indoor and outdoor work, and on ulcer cases. With these were compared estimations on natives belonging

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to other similar tribes, on Masai and on Europeans. The following table summarises the results :—

Blood-pressure—mm.

Tribe.	Kikuyu in-doors	Kikuyu out-doors	Kikuyu all	Others in-doors	Others out-doors	Others all	Masai	Euro-peans	Ulcer cases
Number	40	14	54	31	15	46	28	18	31
Average age	29	28	28	34	32	27	28	29	19
Systolic	110	119	112	111	123	115	117	118	98
Diastolic	78	82	77	79	87	82	79	75	64
Pulse P.	34	37	35	31	36	33	38	41	35
Weight, lbs.	127	130	128	132	128	128	133	—	—

The figures for Europeans correspond fairly closely with the normal standard, with a tendency to be slightly low. This is in agreement with other observations (Breinl and Young, 1919-20: Roddis and Cooper, 1926: Fleming, 1924). The ulcer cases are definitely lower than non-ulcer, and statistical analysis showed the difference to be significant. There is, however, a difference in average age between the two classes, which may account for at least part of the difference in blood pressure. Analysis of the data shows that there is little difference between ulcer cases over 20 years of age and those under 20, the former giving an average of 99 mm. and the latter 98. It is probable, therefore, on the whole that blood pressure may tend to be low in ulcer cases. It is most likely that this depends not so much on the ulcer *per se*, as on the lowered vitality and restricted activity of the patients.

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(*f*) *Blood cell counts.*—Cell counts were made on 28 ulcer cases with 21 non-ulcer cases and eight Europeans as controls. The results were as follows :—

	Europeans.	Non-ulcer natives.	Ulcer cases.
Leucocytes	10,725	9,580	11,978
Erythrocytes	5,825,000	5,580,000	5,667,000
Haemoglobin	91·5%	86·0%	81·2%
Colour index	0·95	0·92	0·85
Polymorphs	64·5	47·0	41·0
Lymphocytes	27·5	41·0	45·0
Large mononuclears	4·2	4·2	7·1
Eosinophiles	4·0	7·1	5·1

There was a lymphocytosis in all natives, ulcer and non-ulcer cases. In ulcer cases the haemoglobin was somewhat low, but the difference is probably not significant. A diminution in polymorphs and increase in eosinophiles has been observed by others in Europeans in the tropics (Breinl and Young, 1919-20).

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(v) *Conclusions.*

In all these blood examinations, the only outstanding point of difference between ulcer and non-ulcer cases is the high inorganic phosphorus in the blood in ulcer. It is of interest to consider the calcium and inorganic phosphorus results together :—

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	Serum calcium, mg. per 100 c.c.	*Inorganic phosphorus, mg. per 100 c.c.*
European standards ..	10·0 to 10·5	.. 3
Europeans in Kenya ..	11·4	.. 3·43
Non-ulcer natives ..	9·4	.. 3·68
Ulcer cases	9·7	.. 4·55

It appears very unlikely that the alteration in balance of calcium and phosphorus in the blood of the natives should be in any way due to environmental influences, since both elements are increased in approximately the same proportion in Europeans. We have already seen that a shift in the direction of high phosphorus, low calcium, occurs in experimental animals on diets containing an excess of phosphorus and deficient in calcium, and the lack of balance in the native dietary, which is closely similar to these experimental diets, would suffice to explain a high phosphorus and low calcium content in the blood. It does not, however, explain the difference between ulcer and non-ulcer cases, for the ulcer cases are so much higher in inorganic phosphate than the non-ulcer that their calcium would be expected to be significantly lower. Instead of being lower, it is at least as high.

It would be of great interest to know whether in the individual case a rise in calcium or phosphorus occurs subsequently to the development of ulcer, and also whether any change occurs in the form in which calcium is present in the blood. It has been suggested by Greenwald and Gross (1925) that part of the calcium may normally be held in solution in the blood as calcium phosphate, which would be physiologically inert. An increase in this fraction might be thought to occur. Further, Ashford and Hernandez (1926), in analyses of the blood of over 500 subjects in Porto Rico, report that blood calcium is low, relatively to accepted standards, especially in cases of " nutritional unbalance," and that the decrease is chiefly in the diffusible fraction.

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It is stated that tropical ulcer cannot be produced by experimental inoculation of the characteristic organisms unless an artificial necrosis of the skin is first produced. (Blanchard, 1914 ; Breinl, 1915.) It does not occur in Europeans, according to Edge (1921), except where the diet is restricted. It would be of the greatest interest to know whether it could be experimentally produced by inoculation of the organisms into animals in which the composition of the blood had first been altered by feeding an ill-balanced, high phosphorus, low calcium diet.

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Foodstuffs.

In Table I the results of the analysis of the 83 samples of foodstuffs are summarised. Where a number of samples of the same substance were received, the average figures and the range are given, all percentages being expressed on the dry matter and in terms of the particular element estimated. In many cases different varieties of the same species of plant were submitted, and certain points may be noted with regard to varietal differences.

Thus, amongst the millets, the three samples of the variety, Mugimbi, submitted, were all richer in ash, calcium, potassium and chlorine, and poorer in sodium, phosphorus and nitrogen, than the average for all the millets, whilst for the three samples of the variety, Mwele, the exact reverse was found. A further difference between the two varieties is shown in the manganese content (*vide* Table II), that of Mugimbi being =40·19 mgms. per 100 gms., whereas that of Mwele is only 2·55. Mugimbi is a red millet, Mwele a white millet.

Twelve different varieties are represented in the figures for plantains, but there do not appear to be any outstanding differences in the composition of the different varieties.

The results for European potatoes cover three varieties, and those for sweet potatoes fifteen varieties. In neither case does any one variety stand out from the rest, although there is a fairly wide range of variation between the extremes. The five different varieties of yams also agree amongst themselves fairly closely.

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The cooked Kikuyu foods show a fair amount of difference amongst themselves, owing to differences in the materials used for compounding them. In the case of Irio, for example, the calcium content is high as compared with all the others, probably owing to the fact that Hatha leaves are incorporated to the extent of roughly one part in eight of the mixture. Ucuru, on the other hand, which consists simply of millet flour, is one of the poorest in mineral content. Ngondi, which is a Masai food, differs from all the Kikuyu foods, in that its ingredients, namely, blood, milk and some fat, are all of animal origin. Its outstanding difference from the other cooked foods is its high nitrogen content.

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TABLE II.—*Manganese Content of Foodstuffs, etc.*

(*Expressed as mgms. of Mn in 100 gms. Dry Matter*).

Foodstuff.	*Mn content.*
Bean	2·36
Maize	0·70
Marrow	2·49
Millet (white)	2·55
„ (red)	40·19
Pea	2·51
Plantain	1·88
Potatoes (sweet)	2·78
Yam	0·20
Cooked Foods.	
Irio	3·51
Kiruyu	4·54
Muthio	3·84
Mukiro	4·03
Musuru	4·70
Ngondi	0·40

/124 cont./

151 proved by the fact that they prepare the ground plan of the huts, the
[804] wire spirals and wire rings serving for adornment, etc., without mechanical measuring devices. For the same reason one recognizes their sense of symmetry in their weapons.

151 Following the Holmgren zephyr-yarn procedures, I examined 87
• 125 Masai, and, to be sure, 46 men and 41 women, on their sense of color. The test showed that of all only one man had "weak color sense," all the others, on the other hand, had "normal color sense."
[822] Here too the symbolic significance of the colors should be considered: black = calm seriousness, red (blood) = war, green = peace, variegated, and, to be sure, especially in the combination of red and white, expresses joy, gaiety, but also frivolity and fickleness.

Photographs of objects known by them they perceived correctly, those of persons known by them not at once, but always only after longer observation. Often the perspective foreshortening of an object in the photograph was incomprehensible to them; they regarded such a one as incomplete.

153 Their powers of orientation in the region and their memory for
151 paths once taken or stretches of land traversed are excellent. Their
153 memory for numbers seems to be better than that of most tribes in the
802 interior of East Africa, since, unlike the latter, they do not use
[211] mechanical aids such as notches in sticks, knots in string, etc. Their power of conceiving numbers does not seem to go beyond five; only a few could recognize at a glance the correct number of more than five objects placed before them.

53 Their feeling for plastic art is shown by the rich and not unhand-
617 some adornment, the handsome forms of their weapons, the painting of the shields, the decoration with cowrie shells and beads on utilitarian objects and clothing. Representational art is unknown to them. A feeling for music is completely lacking; their singing is arbitrary and without rules, the main thing in it is the text and the alternation in the vocal execution. They do not have musical instruments, for the antelope horn of the summoner to legal proceedings serves only to attract the attention of the people through loud noises. The following is a
533 common song to accompany the dance (1):

1. Recorded by Herr Stabsarzt /staff physician/ Dr. Skrodzki.

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[For description of tests and schedules, passim, see category 116, pp. 42-48; 77-84; 198-252; and 319-324.]